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RUN FLAT TIRE FOR C-130 AIRCRAFT

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13. ABSTRACT

Four different constructions in 38.5/28x13-16 size folding sidewall tires were manufactured and evaluated under static and dynamic conditions.

1. Standard construction (3.25" fold depth -6° bead taper)
2. Standard construction - buffed shoulder
3. Deep fold construction (4.75" fold depth)
4. High interference bead fit (10° bead taper)

All constructions showed no bead unseating on static test. However, all constructions showed unseating on dynamic tests. For the various design constructions investigated during Phase I, results showed that an acceptable level was not achieved in improving the 12.50x16 folding sidewall tire's bead seat - run flat operation. For this reason, it was necessary to proceed with bead unseating force measurements, the Phase II alternate approach.

Two different 38.5/28x13-16 tire constructions were used in these determinations.

1. Standard construction (6° bead base taper)
2. High interference bead fit construction (10° bead base taper)

Comparison of the two types of constructions indicates that the standard interference tire (6° bead base taper) was superior to the high interference tire (10° base bead taper), both in respect to bead unseating forces and in mounting the tire on the wheel.

The standard tire showed 30% lower bead unseating force, and bead separation speed was 30 mph faster than the high interference bead tire on the spin-up test. On the landing test, the standard tire showed 246% lower inward force.

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AIRCRAFT TIRES						
COMBAT-DAMAGED						
EXPANDABLE						
COLLAPSIBLE						
FOLDING SIDEWALL						
INFLATABLE						
RUN-FLAT CAPABILITY						
LOADS:						
TIRE BEAD UNSEATING LOADS						

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RUN FLAT TIRE FOR C-130 AIRCRAFT

JAMES W. POND

FOREWORD

This report was prepared by James W. Pond of The B. F. Goodrich Tire Company, Tire Development Department, under USAF Contract F33615-72-C-1191.

The contract was initiated under Project No. 1369, "Mechanical Systems for Advanced Flight Vehicles," and Task No. 136901, "High Performance Landing Gear".

The work was conducted under the direction of Paul M. Wagner, Project Engineer (AFFDL/FEM), Vehicle Equipment Division, Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base, Ohio. The report covers work performed from November 1971 to June 1973.

The author wishes to acknowledge the contributions made by L. G. Beall and J. V. Pavlik of The B. F. Goodrich Company, submitted June 1973.

Publication of this Technical Report does not constitute Air Force approval of the findings, conclusions, or recommendations shown in the report. It is published only for the exchange and stimulation of ideas.

K. H. Digges
KENNERLY H. DIGGES
Chief, Mechanical Branch
Vehicle Equipment Division

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SECTION I

INTRODUCTION

A major deficiency in military aircraft tires is their vulnerability to puncture by small arms fire and by foreign objects on the runway. A punctured tire renders an aircraft immobile and leaves it vulnerable to enemy fire.

This investigation will consist of design improvements leading to the development of tires which will run flat. The foldable sidewall tire's run flat capability has been successfully demonstrated in the laboratory on dynamometers using 9.50-16 and 23.00-20 size tires. However, when these design features were extended to other aircraft tires of various intermediate and large sizes, unseating of the tire beads occurred during run flat operation.

A successful run flat landing was accomplished on both an aircraft and the laboratory dynamometer, using bead spacer mechanism in a 12.50-16 foldable sidewall tire. While this bead spacer mechanism was a workable design, it is not acceptable on a retrofit basis due to weight and installation disadvantages.

SECTION II

OBJECTIVE AND SCOPE

The purpose of this program is to investigate, design and develop C-130 aircraft tires which will operate when flat. The foldable sidewall-expandable-tire configuration will be used.

EFFORT ON THIS PROGRAM IS TO BE DIRECTED TOWARD:

1. Experimental investigation of existing run-flat operational limitations.
2. Refinements based on experimental results.
3. Analysis to translate experimental results to a larger size tire, or the design of an optimized bead locking system.

For convenience in program definition, the work is divided into two phases.

Phase I shall consist of a series of 12.50-16 foldable sidewall design-fabrication-experimentation iterations in order to perfect the tire's run-flat operation.

Phase II shall consist of an analysis which will translate Phase I experimental results to the 20.00-20/26 PR size foldable sidewall tire. Phase II-Alternate is included in this phase if the Phase I approaches to the run-flat problem are not successful. This investigation will include measurements to determine the forces generated during unseating of the tire beads. Such force determinations will be made of the folded tire under static load, undeflected spin-up and combined load and speed conditions.

SECTION III

SUMMARY AND RECOMMENDATIONS

A. PHASE I

Four different constructions in 38.5/28x13-16 size tires were manufactured and evaluated under static and dynamic conditions.

1. Standard construction (3.25" fold depth -6° bead taper)
2. Standard construction - buffed shoulder
3. Deep fold construction (4.75" fold depth)
4. High interference bead fit (10° bead taper)
   These are shown in Figure II

All constructions showed no bead unseating on static test. However, all constructions showed unseating on dynamic tests. For the various design constructions investigated during Phase I, results showed that an acceptable level was not achieved in improving the 12.50x16 folding sidewall tire's bead seat - run flat operation. For this reason, it was necessary to proceed with the Phase II alternate approach.

B. PHASE II - Alternate

Bead unseating force measurements were conducted at the B.F.Goodrich Wheel and Brake Plant at Troy, Ohio, under the direction of Mr. J. V. Pavlik. Two different 38.5/28x13-16 tire constructions were used in these determinations.

1. Standard construction (6° bead base taper)
2. High interference bead fit construction (10° bead base taper)

Spin-up test	Maximum Inward Force	Speed at Start of Load Build-UP
Standard construction	1705 lbs.	130-150 Range
High interference construction	2280	100-120 Range
Landing test		
Standard construction	681 lbs. (@111 mph)	
High interference construction	1682 lbs. (@101 mph)	

Comparison of the two types of constructions indicates that the standard interference tire (6° bead base taper) was superior to the high interference tire (10° base bead taper), both in respect to bead unseating forces and in mounting the tire on the wheel.

The standard tire showed 30% lower bead unseating force, and bead separation speed was 30 mph faster than the high interference bead tire on the spin-up test. On the landing test, the standard tire showed 246% lower inward force.

The data obtained in tests, conducted at Troy, on the high interference bead fit tire are not consistent with those data obtained on the Brecksville dynamometer. Troy data shows greater inward force with the high interference bead fit construction but tests at Brecksville showed this construction to be better than the standard construction for bead pull off. We have no suitable explanation for this inconsistency.

C. Recommendations

1. Bead-Spacer Mechanisms

It has been demonstrated that such devices can be used to prevent bead unseating during run flat operation of the tire. However, there are disadvantages to the use of such devices including but not limited to:

(a) weight penalty

(b) increased assembly complexity

(c) additional parts inventory

(d) possible damage to tire beads during the mounting and normal operation (depending on spacer design)

Three types of bead-spacer mechanisms are shown in Report AFFDL-TR-71-118 prepared by Paul M. Wagner, pages 88,89, and 90.

2. Wheel modifications

It is recommended that a "hump" be machined into the wheel. The hump would be located immediately inside of the bead, and would be effective in preventing bead unseating.

In addition, this type of wheel design would result in:

(a) minimum weight penalty

(b) lower cost than separate bead spacer mechanisms

(c) no extra parts or components

(d) improved assembly condition

(e) wheel stress would not be affected

(f) the wheel would remain completely convertible, in that it could be used with both collapsible and non-collapsible tires.

No particular problem should be encountered in seating beads, over the "hump" of the wheel, using normal inflation pressure. Bead unseating, during tire dismounting and removal from the wheel, is likely to be more difficult, and special tools for dismounting tires may be required.

The only major disadvantage to this solution to the bead unseating problem, is that it is not applicable on a retro-fit basis. A suggested bead hump profile and location is shown (Figure No. III).

3. In the event that a new wheel design is completely unacceptable, it is suggested that consideration be given to the type 3 bead spacer (technical report AFFDL-TR-71-118, page 90) modified to reduce weight to an acceptable level.

It is suggested that a suitable aluminum alloy be used for type 3 bead spacer components which would have an estimated weight increase of approximately one (1) pound per tire assembly compared to 2.55 pounds for the type 3 fabricated from steel.

SECTION IV

EXPERIMENTAL PROGRAM - Phase I-38.5/28x13-16 Tire BEAD UNSEATING TESTS - Zero Inflation

A. Indoor Test Conditions - Special Tests
For 38.5/28x13-16 Foldable Sidewall Tire
Basic constructions are shown by Figure II

1. Inflate tire to sufficient pressure to seat beads, then deflate.
2. With valve core out, slowly load tire against the wheel until beads unseat (Maximum load 10,000 lbs.). Record load.
3. Inflate tire to seat beads, then deflate.
4. With valve core in, slowly load tire against wheel until beads unseat. (maximum load 10,000 lbs.). Record load.
5. Inflate tire to seat beads, then deflate.
6. Valve core in, zero pressure, spin up tire, using minimum wheel contact until tire unfolds, record speed, then continue spin up until beads unseat or 160 mph whichever occurs first. Record speed.
7. Inflate tire to seat beads, then deflate.
8. Valve core out, spin up tire, using minimum wheel contact, until tire unfolds, record speed, then continue spin-up until beads unseat or 160 mph whichever occurs first. Record speed.
9. Valve core in, zero inflation load tire against wheel, retract when beads unseat. Deceleration rate 4.5/ft/sec./sec.

	SPEED	LOAD
Run No. 1	60 to 0 MPH	4500 lbs.
Run No. 2	75 to 0 MPH	6000 lbs.
Run No. 3	90 to 0 MPH	75000 lbs.
Run No. 3	105 to 0 MPH	8150 lbs.
Run No. 4	111 to 0 MPH	8150 lbs.
Run No. 5	111 to 0 MPH	9400 lbs.

10. Inflate tire to seat beads, then deflate.

11. Valve core out, repeat conditions in step 9.

B. STATIC TESTS (Steps 1,2,3, and 4)

1. Standard construction (3.25" sidewall fold depth and 6° bead base taper)

   (a) 12.50x16 wheel (10" width)

      (a1) 10,000 lb. load, valve core out, beads remained seated.

      (a2) 12,000 lb. load, valve core in, beads remained seated.

   (b) 40x14 wheel (11" width)

      (b1) 10,000 lb. load, valve core in, beads remained seated.

2. Standard Construction - Buffed Shoulder.

   (a) 12.50x16 wheel, valve core in.

      12,000 lb. load beads remained seated.

3. Deep sidewall Fold Construction (4.75" sidewall fold depth)

   (a) 12.50x16 wheel, valve core in.

      12,800 lb. load, beads remained seated.

4. Interference Bead Fit construction (10° bead base taper)

   (a) 12.50x16 wheel, valve core in.

      12,800 lb. load, beads remained seated.

B. Spin-up Test (160 mph maximum speed)

1. Standard Construction

(a) 12.50x16 wheel, valve core in.

(a1) Tire unfolded at 70-75 mph.

(a2) Beads unseated at 100 mph.

(b) 40x14 wheel, valve core in.

(b1) Tire unfold at 85 mph.

(b2) Beads unseated at 85 mph.

2. Deep Sidewall Fold Construction

(a) 12.50x16 wheel, valve core in.

(a1) Tire unfold at 65 mph.

(a2) Bead unseated at 70 mph.

3. Interference Bead Fit Construction

(a) 12.50x16 wheel, valve core in.

(a1) Tire unfolded-speed not recorded

(a2) Beads remained seated at 160 mph.

(b) 12.50x16 Wheel, valve core out

(a1) Tire distorted- There may have been bead unseating

(far side of dynamometer wheel)

speed not recorded

C. Landing Tests

1. Standard Construction

(a) 12.50x16 wheel, valve core in.

(a1) 60 to 0 mph. 4,500 lb. load, beads remained seated.
(a2) 75 to 0 mph. 6,000 lb. load, beads remained seated.
(a3) 90 to 0 mph. 7.500 lb. load, beads unseated quickly

(b) 40x14 wheel, valve core in.

(b1) 75 to 0 mph, 6,000 lb. load, beads unseated quickly.

2. Normal Construction - Buffed Shoulder.

(a) 12.50x16 wheel, valve core in.

(a1) 60 to 0 mph-4,500 lb. load - beads remained seated

(a2) 75 to 0 mph-6,000 lb. load - beads remained seated

(a3) 90 to 0 mph-7,500 lb. load - beads unseated at 75 mph.

3. Deep Sidewall Fold Construction

(a) 12.50x16 wheel - valve core in.

(a1) 75 to 0 mph-6,000 lb. load - beads unseated quickly.

4. Interference Bead Fit Construction.

(a) 12.50x16 wheel - valve core in.

(a1) 75 to 0 mph, 6,000 lb. load - beads remained seated

(a2) 90 to 0 mph, 7,500 lb. load.

Run No. 1, beads unseated quickly

Run No. 2, beads remained seated at the start of the run, speed remained at 90 mph for 12 seconds before start of ramp. Tire was failing as evidenced by large volume of smoke. Beads unseated sometime during the "smoke" period. However, the tire completed the run.

SECTION V

EXPERIMENTAL PROGRAM-PHASE II-ALTERNATE DETERMINATION OF BEAD UNSEATING FORCES.

TEST SET-UP:

The wheel used for testing was a modified 3-929-1 (707-320) nose wheel. To measure bead loads, three ring-type load cells were manufactured, as shown in Figure X, and were installed on the wheel at 120 degree intervals, as shown in Figure XI. Closer inspection of Figure X shows an adjustment screw on the end of the load cell for load cell adjustment and preload. This adjustment is made from a one inch diameter hole drilled through the wheel tubewell shown in Figure XI. Load cell wires are also threaded through this hole. Figure XII shows an Allen screw mounted on the bearing grease seal cover. This screw, combined with a sensor pickup on the axle, tells the exact position of each load cell during the test.

TEST PROCEDURE:

Two different configuration tires were tested. One was a standard collapsible tire (N51-0099-3). The other was a non-standard collapsible tire having an increase bead interference fit (N51-0192-4). Each tire completed three spin-ups to 160 mph and one landing cycle. In the spin-up mode, the tire was positioned against the roadwheel and backed off by the rolling radius adjustment motor as the tire expanded. This method did not allow for a true spin-up as the tire saw some load when in contact with the roadwheel. The landing cycle included touchdown at 111 mph at a radial load of 9,400 lbs. with a roadwheel inertia of 10391 lbs. Stop time averaged about three minutes.

Before each part of the test, the tire beads were seated and a preload of 25 lbs. applied to each load cell. Also all testing was done in an unsealed condition. This means that the wheel was vented to the outside atmosphere (through the adjustment holes).

RESULTS:

Figures XIII thru XV show the bead loads produced with the standard tire during spin-up. Run number 1 (Figure XIII) shows the highest loads and indicates a maximum load of 1,705 lbs. required to resist bead movement. Note that the bead load started to build in the 130-150 mph range.

Figures XVI thru XVIII show the bead loads produced with a non-standard tire during spin up. Again, run number 1 (Figure XVI) shows the highest loads and indicates a maximum load of 2,280 lbs. required to resist bead movement. (Load cell number 1 which went out was assumed to be identical to load cell number 2). The bead load started to build in the 100-120 mph range.

Not shown in Figures XIII thru XVIII is the fluctuation in load cell readings as the tire crossed the roadwheel. The oscillograph trace showed an increase in load just prior to and immediately follo[illegible] roadwheel contact with a load decrease at the roadwheel contact point. [illegible] iations in load tend to fluctuate about a load recorded when the load cell is opposite the roadwheel contact point. This reading is more indicative of a tire spin-up and therefore this is the load recorded.

Figure XIX shows the bead loads produced with the standard tire during a run flat landing condition. The maximum load required to resist bead separation is 681 lbs. at 111 mph. (Load cell number 2 went out at 91 mph. It should be noted that throughout the test, when a load cell went out, it was not the load cell itself that was damaged but always it was a wire lead to the slip ring that had frayed or broken).

Figure XX shows the bead load produced with the non-standard tire during a landing run. The maximum load required to resist bead separation is 1,682 lbs. at 101 mph.

There was also a fluctuation in load cell readings as the load cell crossed the roadwheel as was the case during the spin-up testing, except the load fluctuation was completely reversed. The oscillograph trace showed a load decrease just prior to, and immediately following, roadwheel contact with a load increase at the roadwheel contact point. This increased load (load at contact) is the load recorded in Figures XIX and XX.

This load decrease with the standard and non-standard tire varied from 30% of the high load down to 0% at zero velocity, and 50% of the high load down to 0% at zero velocity respectively.

Observation of the 38.5/28x13-16 tire, after test at Troy, showed tread and liner abrasion as well as some reversion of the sidewall compound at the area. This abrasion is probably the result of light contact; the tread against the roadwheel and the liner against the folded part. The reverted sidewall is the result of high temperature at this natural location of energy absorption.

Photographs of the two tire constructions tested at Troy have been made and are included.

The rapid increase in inward force, tending to unseat the beads, is probably due to the change in the tire profile as the speed is increased. High speed photographs, which were not made during these tests, would be required to confirm this contention.

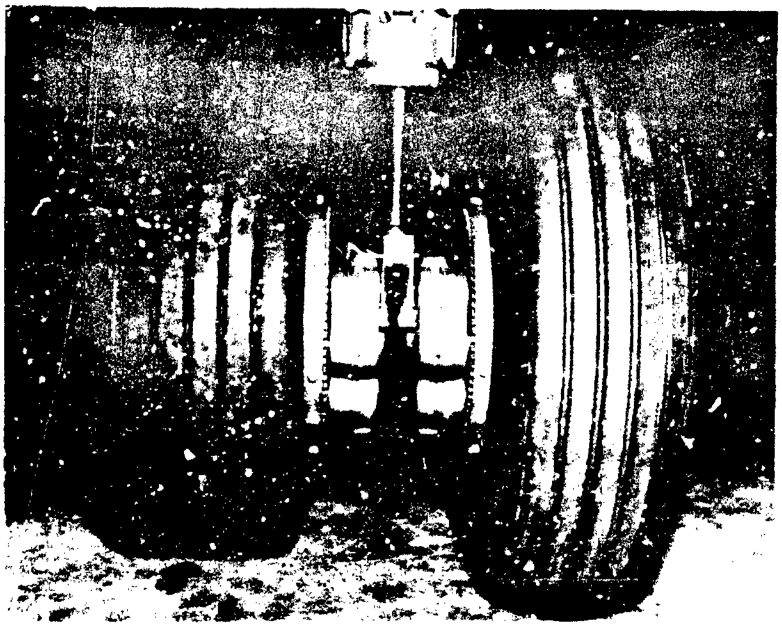


FIGURE I
Uninflated and Inflated

BY L.W. Pond DATE 8-12-73	SUBJECT 38.5/28x13-16	SHEET NO. ____ OF ____
CHKD. BY ______ DATE ______	Foldable Sidewall Tire	JOB NO. ______

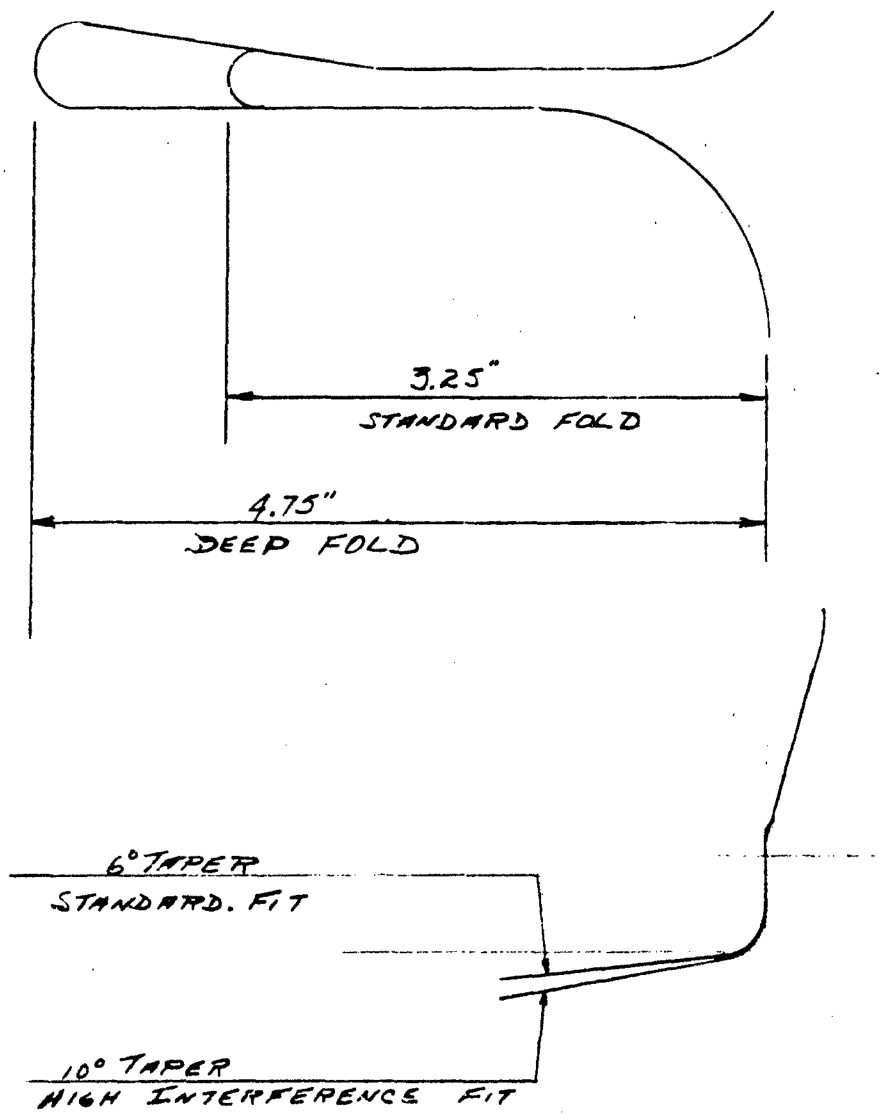


FIGURE III
Sketch showing the four basic constructions that were evaluated in this project.

BY I.W. Pond DATE 6-14-73 SUBJECT 12.50x16 Wheel Hump Type For Special Aircraft Tires SHEET NO. ____ OF ____
CHKD. BY ____ DATE ____ JOB NO. ____
Figure III

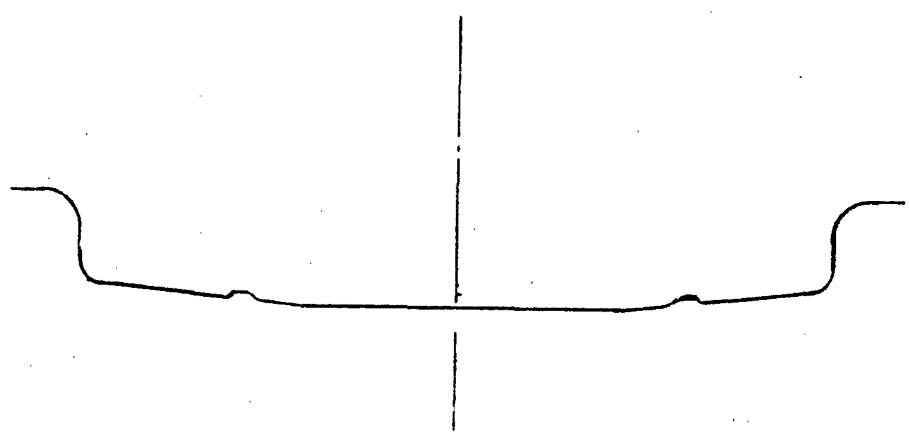


FIGURE III
Sketch showing a suggested wheel hump.

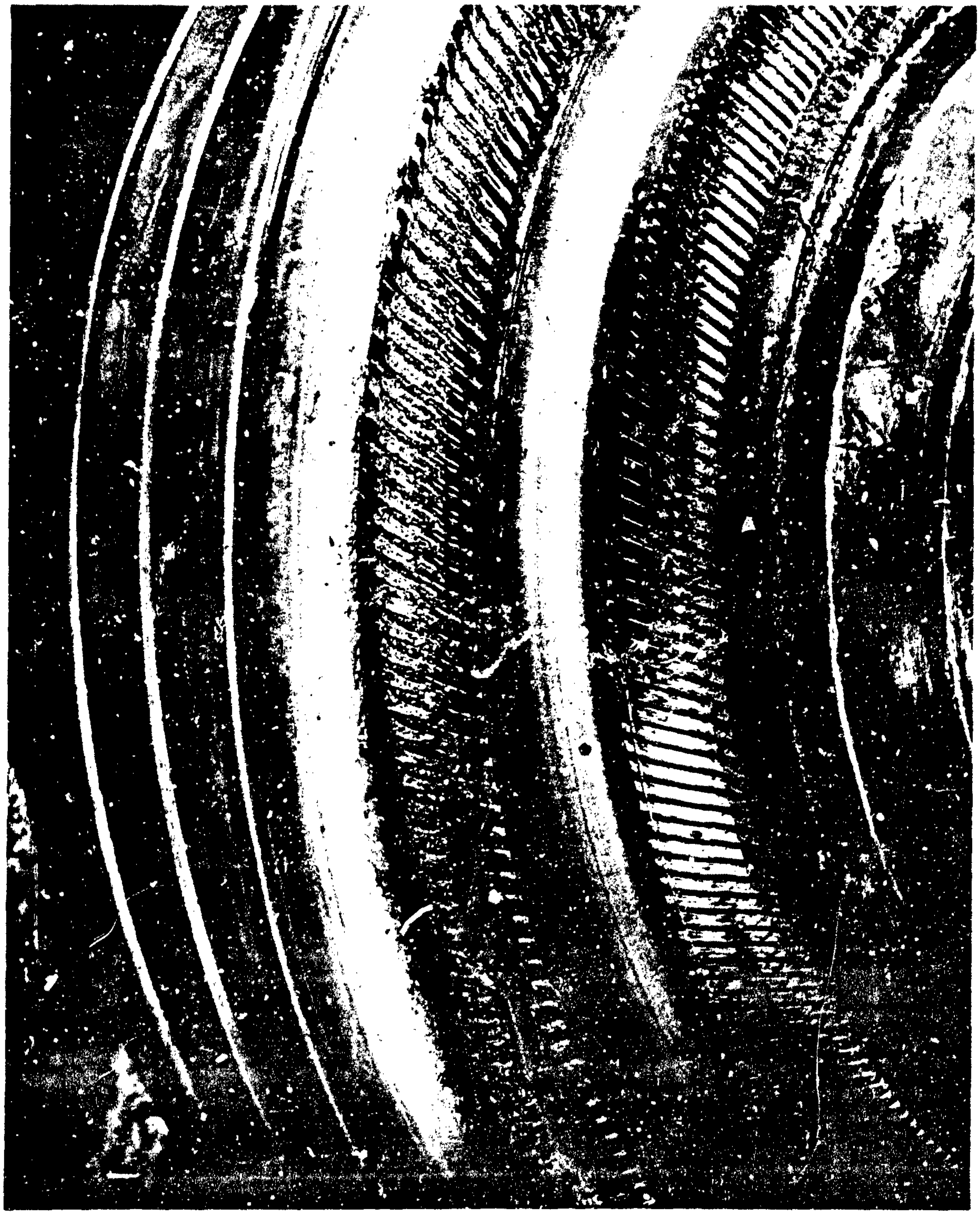


FIGURE IV
Standard Tire After Troy Test-Sidewall

FIGURE V
Standard Tire After Troy Test-Trend

FIGURE VI
Standard Tire After Troy Test-Liner

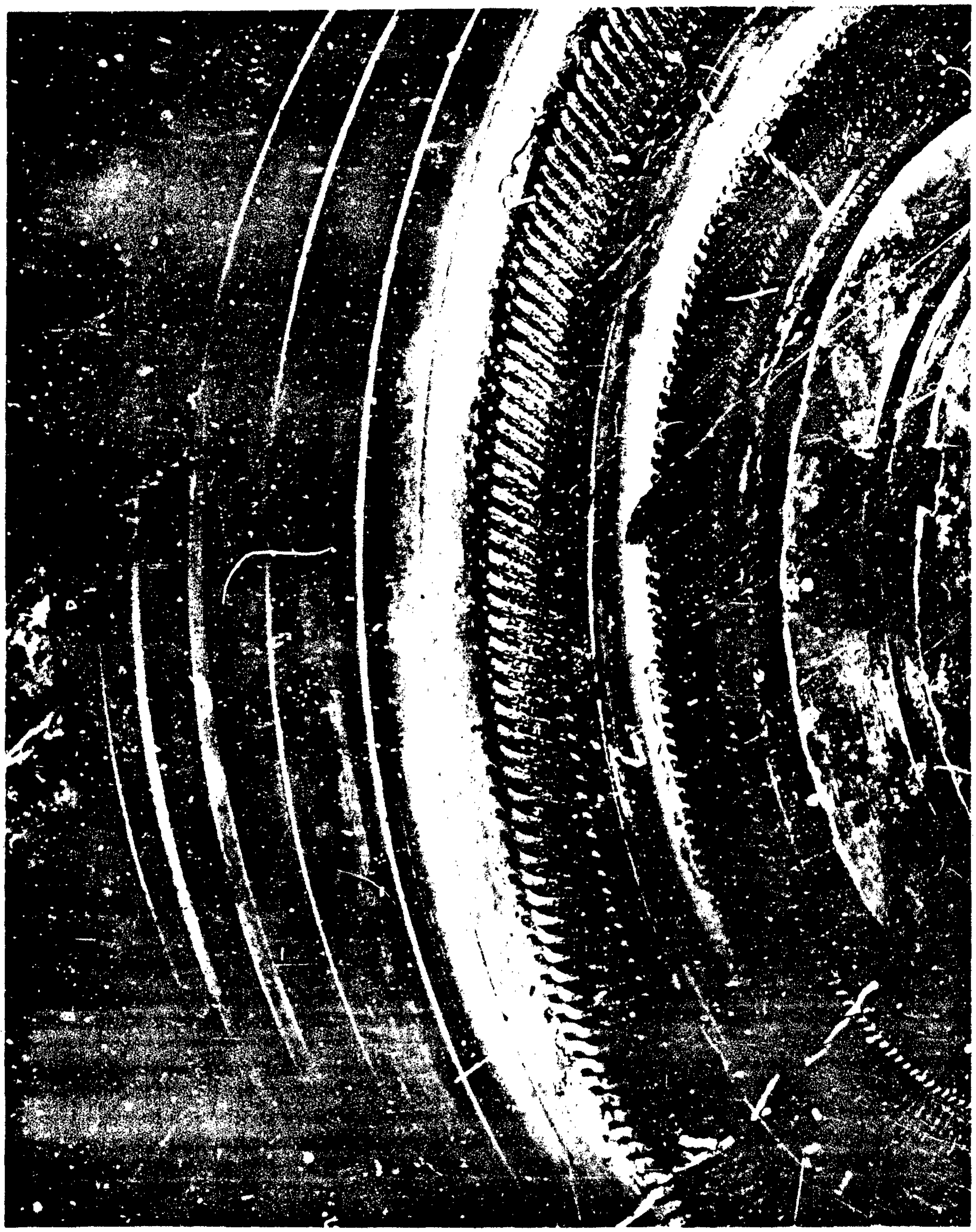


FIGURE VII
Non-Standard Tire After Troy Test-Sidewall

FIGURE VIII
Non-Standard Tire After Troy Test-Tread

FIGURE IX
Non-Standard Tire After Troy Test-Liner

FIGURE X
Load Cell Design-Troy Tests

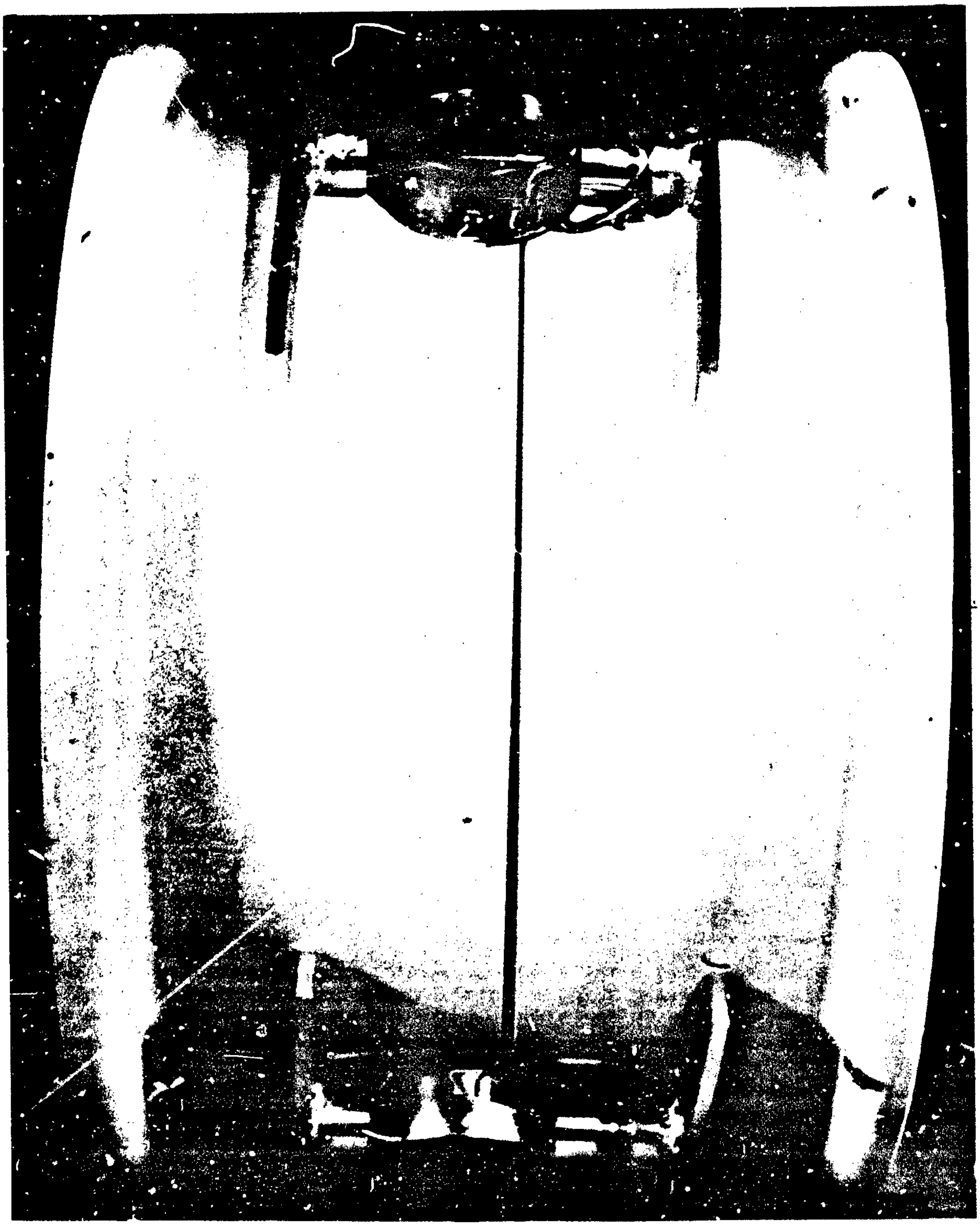


FIGURE XI
Load Cell Placement--Troy Tests

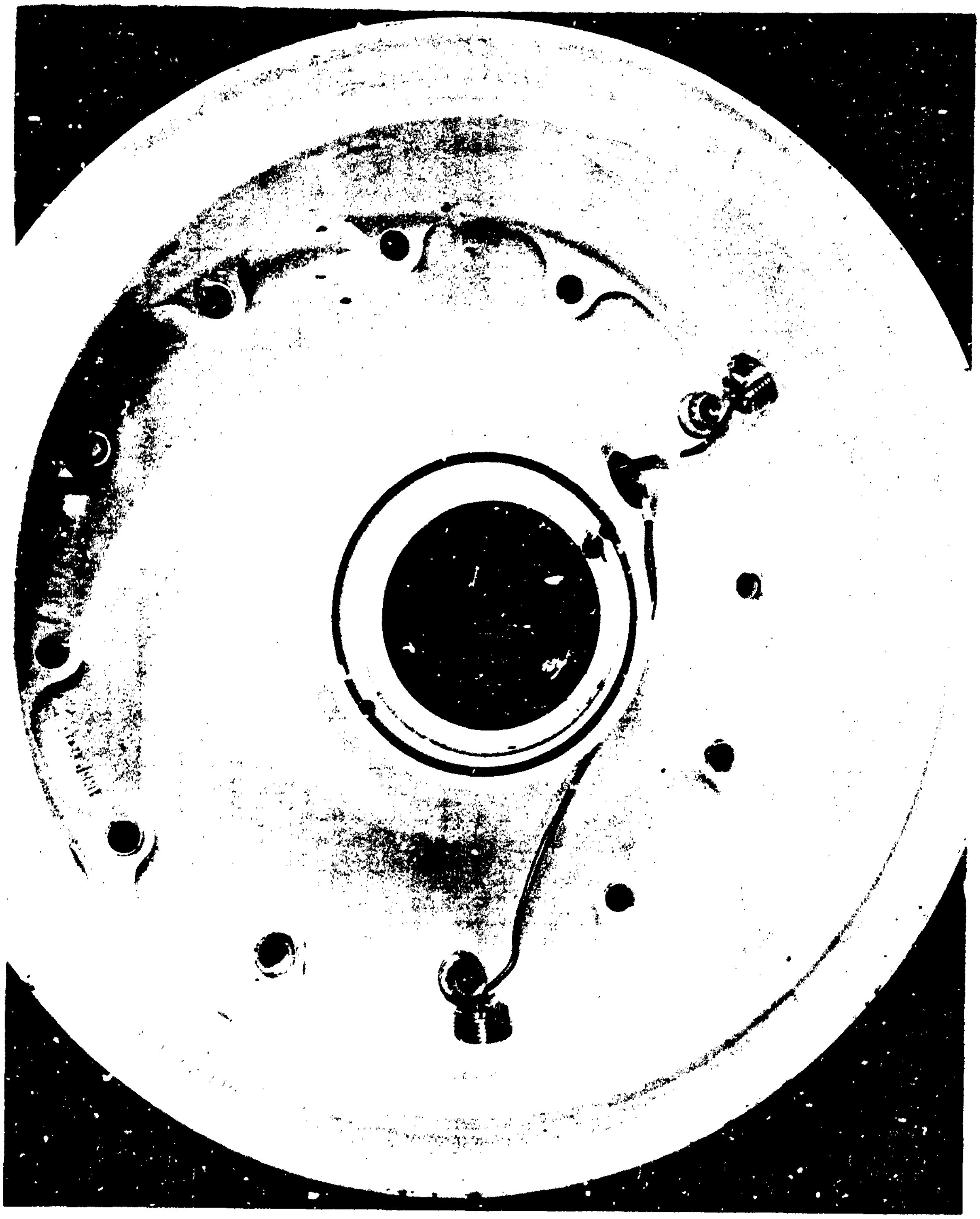
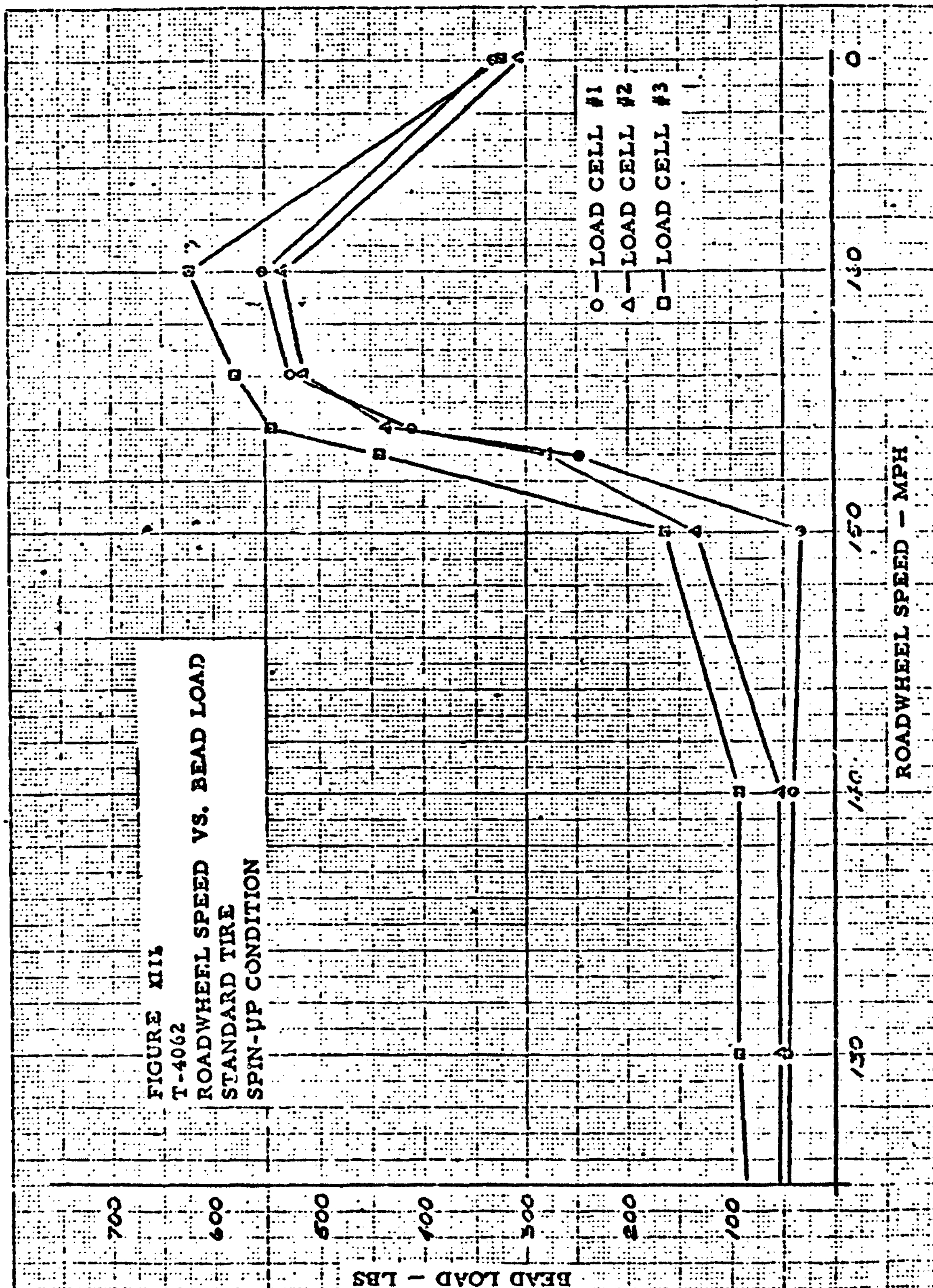
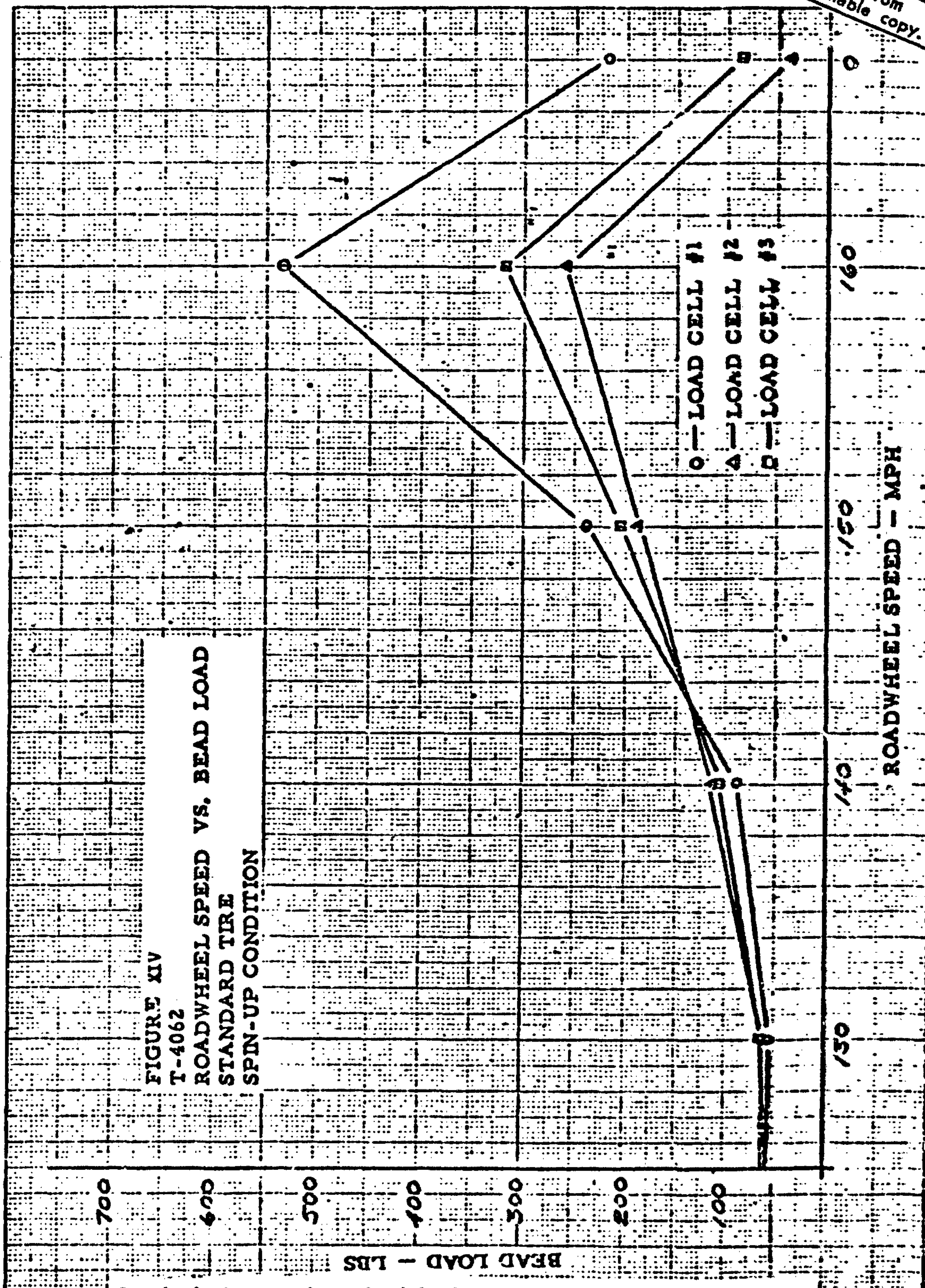


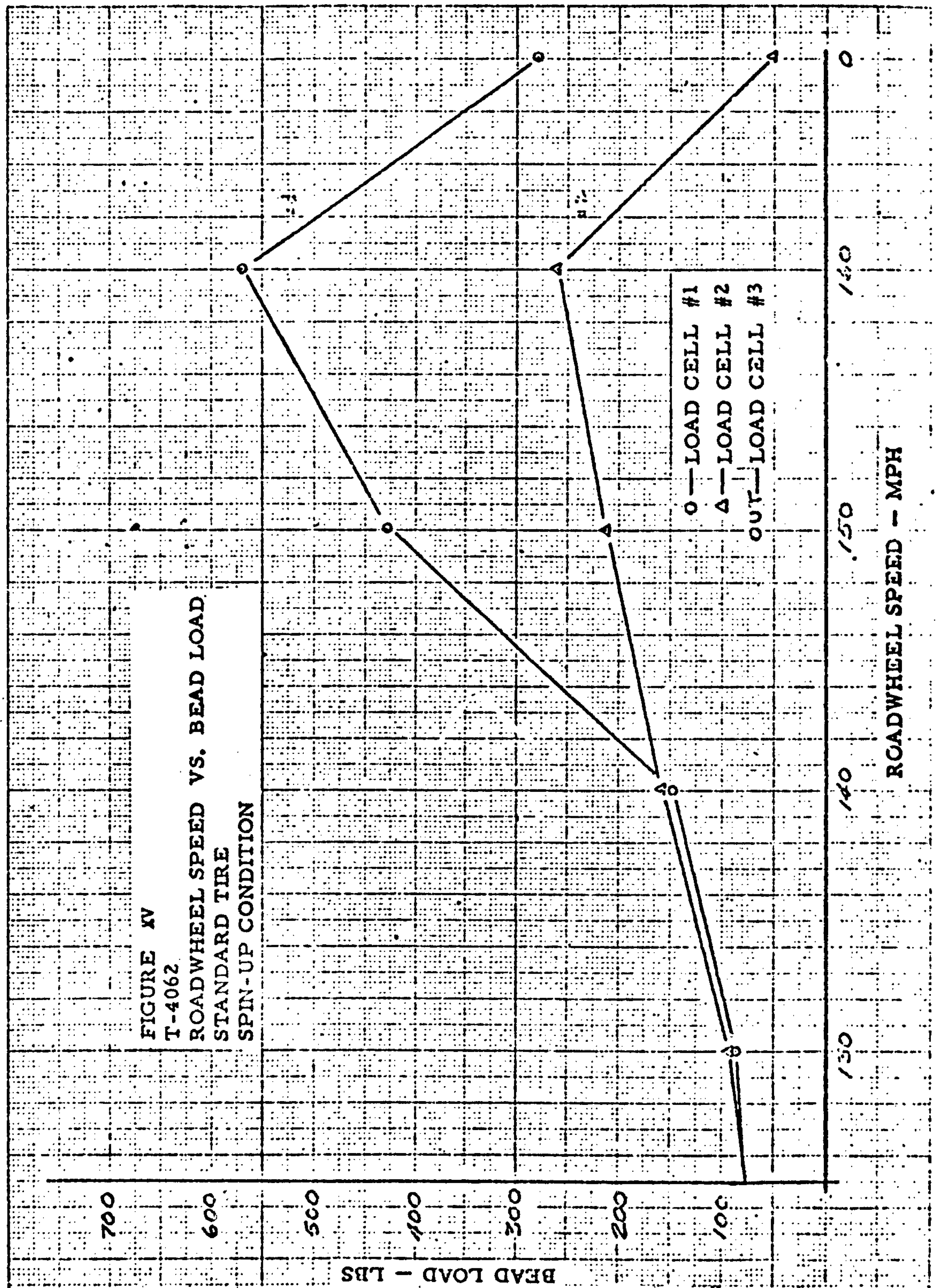
FIGURE XII
Position Sensor-Troy Tests



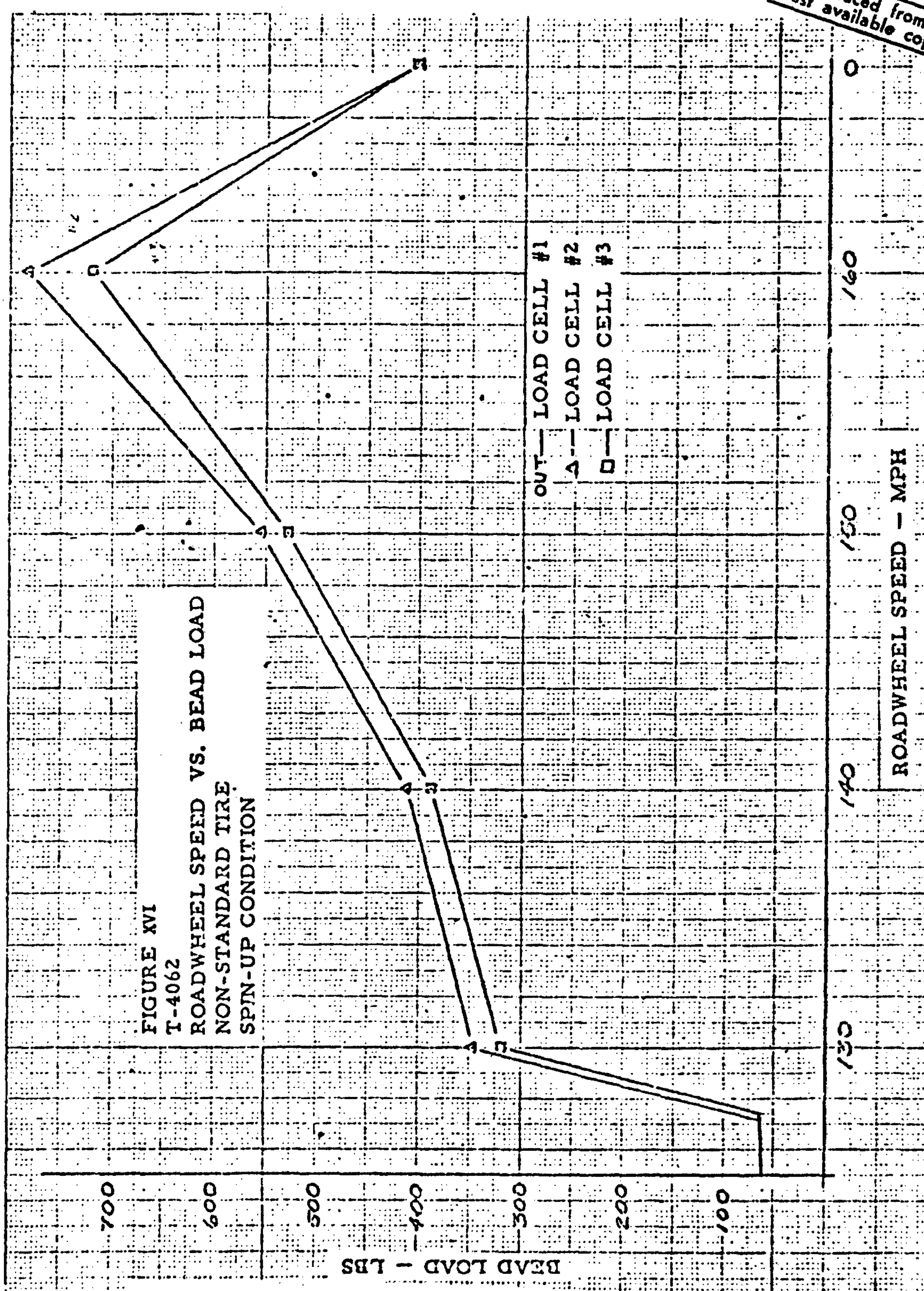
Standard tire speed vs. bead load,-spin-up condition. Run No. 1



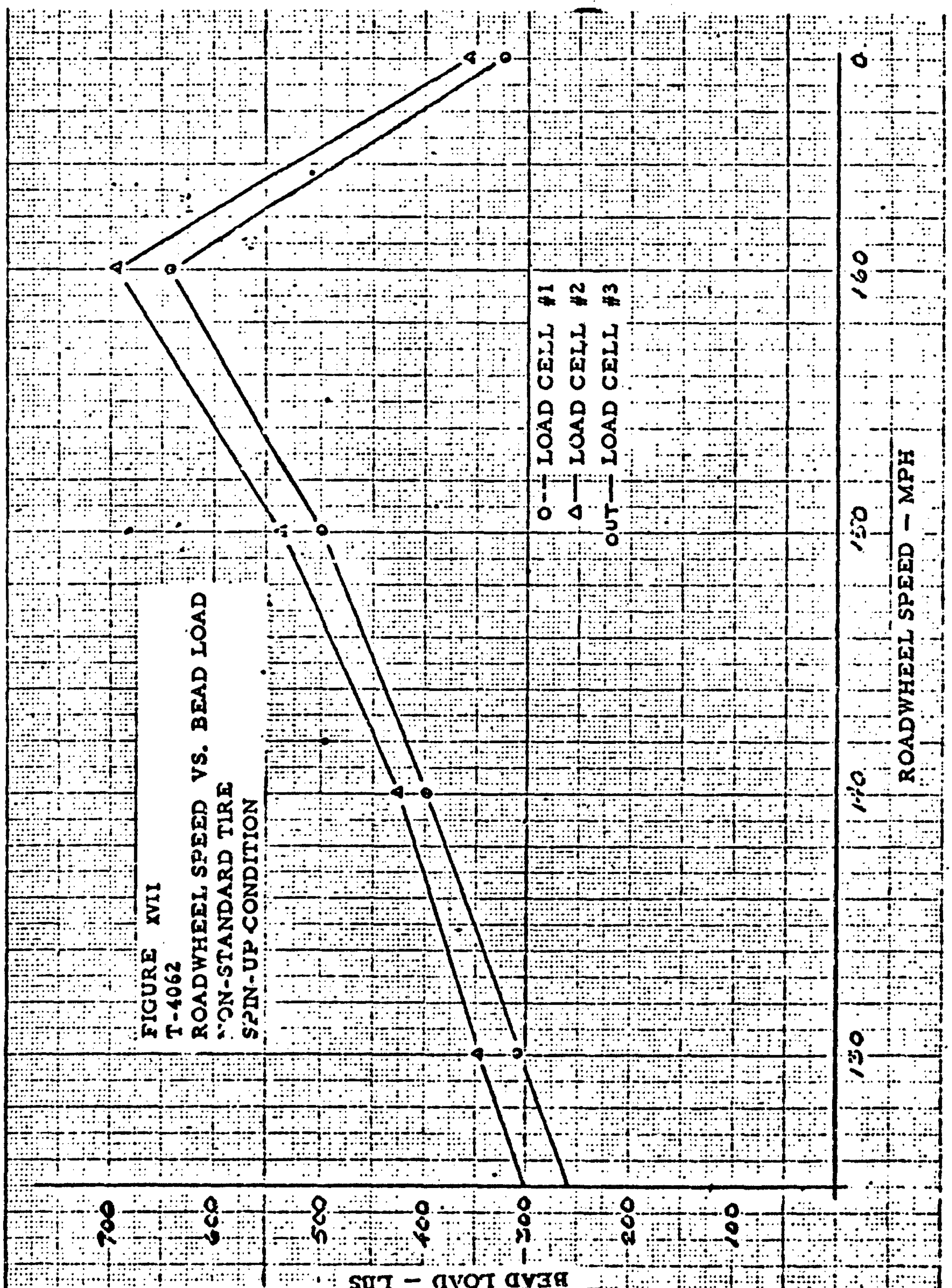
Standard tire-speed vs. bead load,-spin-up condition. Run No. 2



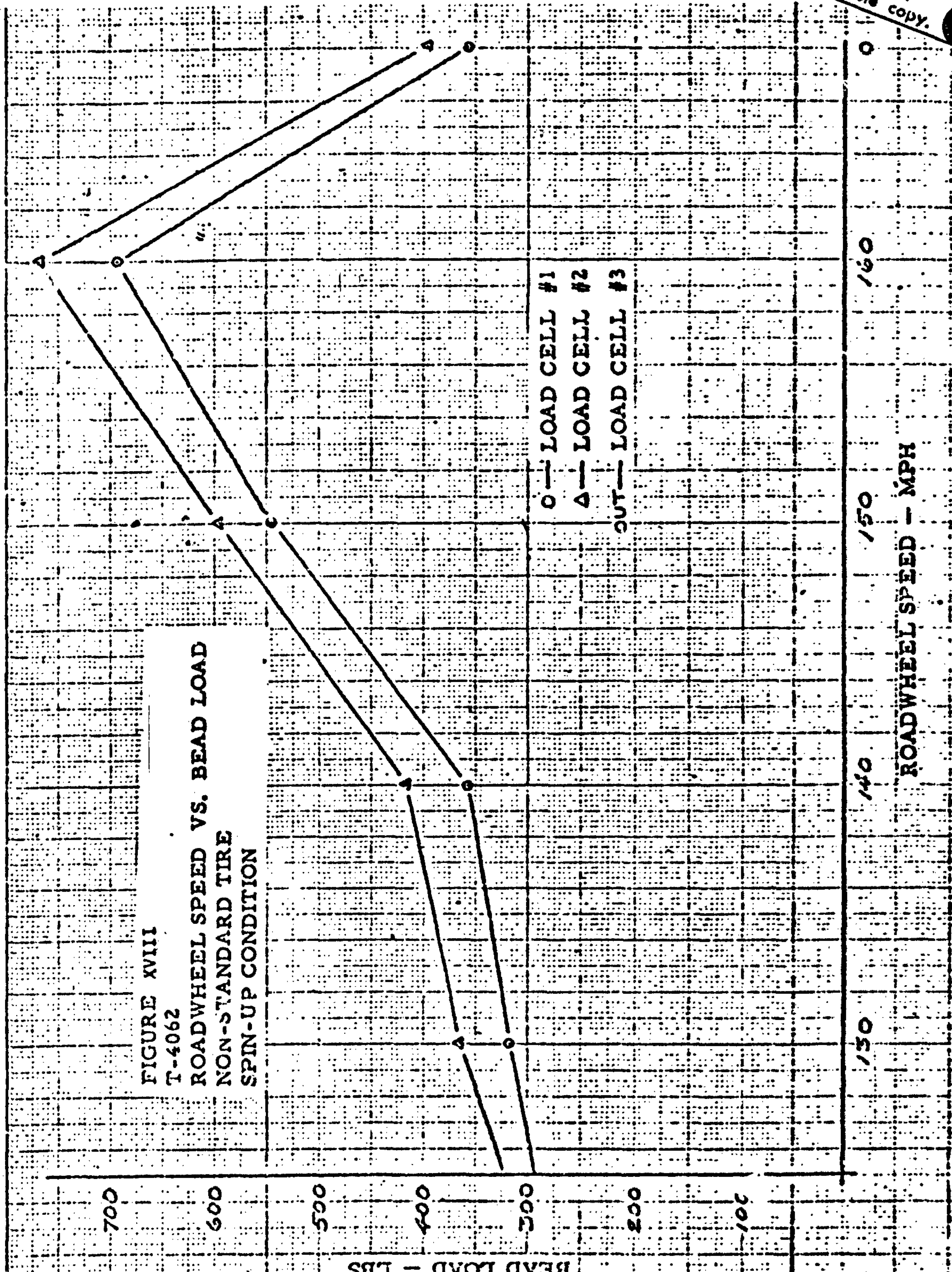
Standard tire-speed vs. bead load, spin-up condition. Run No. 3



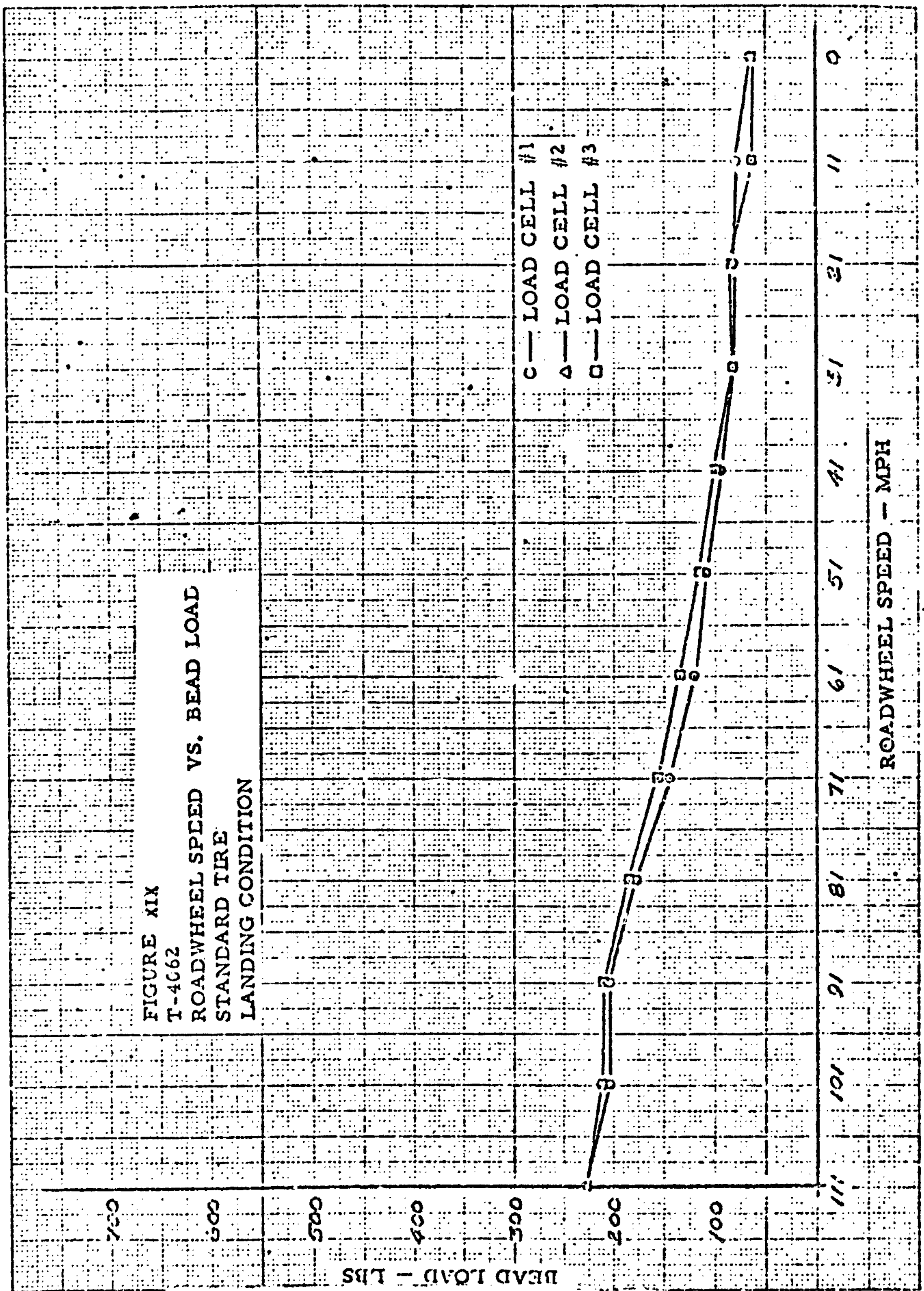
Non-standard tire speed vs. bead load, spin-up condition. Run No. 1



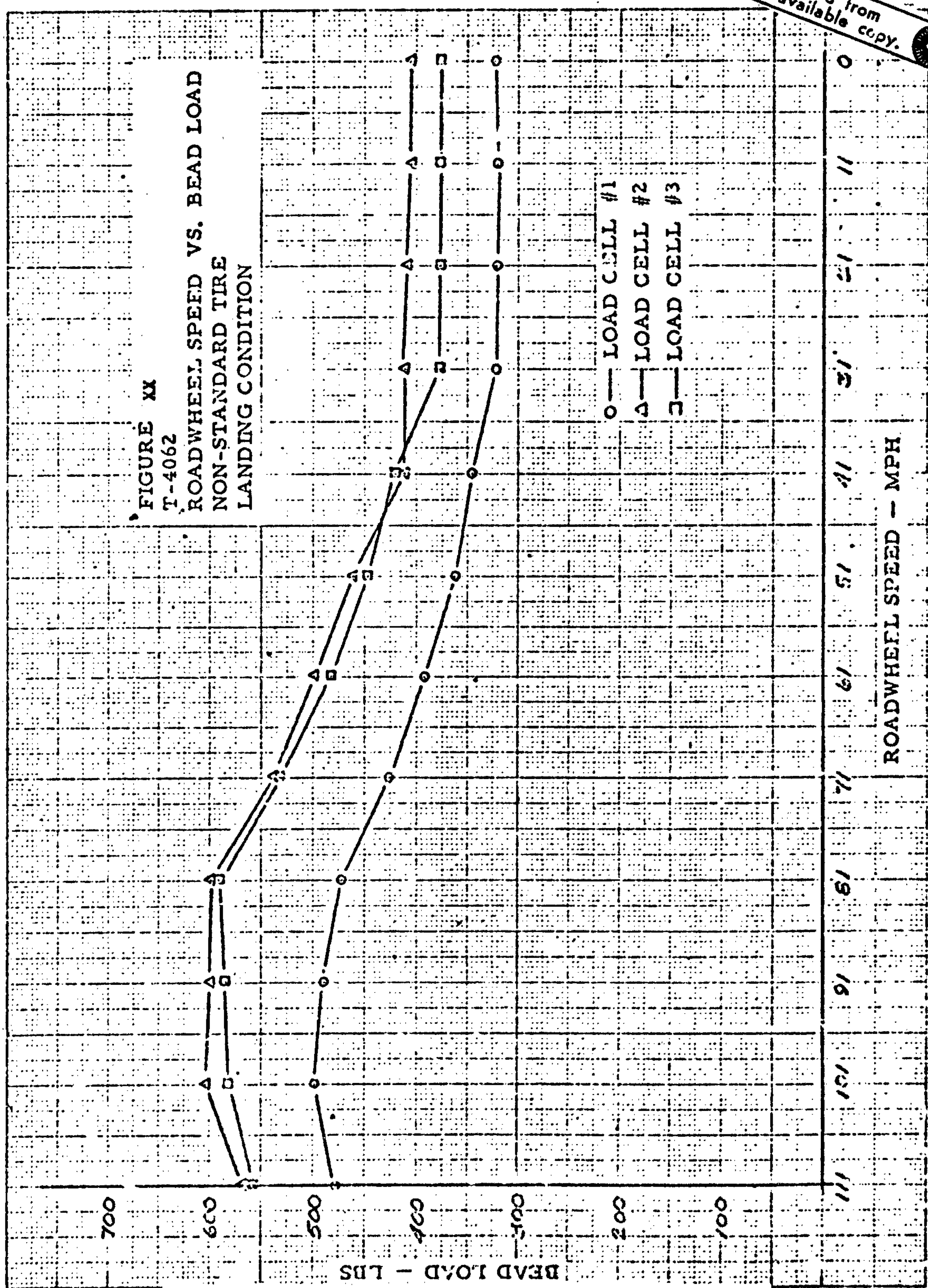
Non-standard tire speed vs. bead load, spin-up condition. Run No. 2



Non standard tire speed vs. bead load, spin-up condition. Run No. 3



Standard tire-speed vs. bead load - landing condition.



Non-standard tire-speed vs. bead load - landing condition.